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Analysis of Sahelian vegetation dynamics using NOAA-AVHRR NDVI data from 1981–2003

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Abstract

Remotely sensed measurements from NOAA-AVHRR expressed as normalized difference vegetation index (NDVI) have generated a 23-year time series appropriate for long-term studies of Sahel region. The close coupling between Sahelian rainfall and the growth of vegetation has made it possible to utilize NDVI data as proxy for the land surface response to precipitation variability. Examination of this time series reveals two periods; (a) 1982–1993 marked by below average NDVI and persistence of drought with a *signature* large-scale drought during the 1982–1985 period; and (b) 1994–2003, marked by a trend towards 'wetter' conditions with region-wide above normal NDVI conditions with maxima in 1994 and 1999. These patterns agree with recent region-wide trends in Sahel rainfall. However taken in the context of long-term Sahelian climate history, these conditions are still far below the wetter conditions that prevailed in the region from 1930 to 1965. These trend patterns can therefore only be considered to be a gradual recovery from extreme drought conditions that peaked during the 1983–1985 period. Systematic studies of changes on the landscape using high spatial resolution satellite data sets such as those from LANDSAT, SPOT and MODIS will provide a detailed spatial quantification and description of the recovery patterns at local scale.

Keywords: NOAA-AVHRR; NDVI time series; Sahel; Drought

1. Introduction

The Sahel is a semi-rid region stretching approximately 5000 km across northern Africa from the Atlantic Ocean in the west to near the Red Sea in the east and extending roughly from 12°N to 18°N. This region forms an ecological transition between the Sahara desert to the north and the humid tropical savanna to the south (Le Houerou, 1980). The characteristic vegetation types constitute mixtures of grasslands, shrubs and thorny trees. In general, the precise geographic location of the Sahel is difficult to distinguish because these physical characteristics change over

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time and space (Le Houerou, 1980; Monod, 1986). Generally, the northern limit is defined by the 100–200 mm/year rainfall contour and the southern limit by the 400–600 mm/year as shown in Fig. 1a. The rainfall regime in the region is characterized large variations from year to year compounded by persistent long-term drought since the early 1970s. Since the mid 1960s this region has experienced a systematic decrease in rainfall and wide spread droughts affecting the larger area of Sub-Saharan Africa (Tanaka et al., 1975; Bunting et al., 1976; Nicholson, 1979; Lamb, 1982). These large variations and trends in rainfall have attendant impacts on vegetation dynamics and availability of food and fiber for the people of the region.

4. Summary and conclusions

Satellite measurements of Sahelian vegetation dynamics during the last 23 years have provided a comprehensive picture of the patterns of land surface interannual variation and trends. The persistence and spatial coherence of drought conditions during the 1980s is well represented by the NDVI anomaly patterns and corresponds with the documented rainfall anomalies across the region during this time period. The prevalence of greener than normal conditions during the 1990s to 2003, follows a similar increase in rainfall over the region during the last decade (Nicholson, 2005). In general, the time series trends in NDVI indicate a greening pattern across the region with the most systematic pronounced increases in the central Sahel region. The period 1981–1990 is dominated by below normal conditions with 80% of the years showing below normal NDVI conditions with severest departures in NDVI in 1984 (2.5 standard deviations below the mean) persisting for 6 years between 1982 and 1987, with exception of 1981, 1988 and 1989. These patterns are summarized in Table 1 and Fig. 7. Between 1991 and 2003, 76% of the years show above normal vegetation conditions with 1994 and 1999 showing ~1.5 standard deviations above the long-term mean with only 1991, 1993 and 2002 showing below normal conditions (Fig. 7). The persistent nature of these two different patterns in NDVI between 1981–1990 and 1991–2003 is in agreement with the historical patterns of rainfall anomalies in the region (Nicholson, 2001). In the context of the long-term changes in the Sahel region, the conditions in the last two decades are still far below rainfall conditions that prevailed across the region between 1930 and 1965 (Fig. 7).

What the NDVI time series data indicates is that there is a gradual and slow but persistent recovery from the peak drought conditions that affected the region in the early to mid-1980s. This is corroborated by the decrease in the magnitudes of negative rainfall departures from 1984 to 2000 (Fig. 7). The correlation between the NDVI and rainfall anomaly time series for the 1981–2000 period is positive and significant ($r = 0.78$, $p < 0.01000$) indicating the close coupling between rainfall and land surface response patterns over the region. The large scale and coherent changes in anomaly patterns between 1984 and 1994, a difference of 10 years might suggest some large-scale climatic influence on Sahelian vegetation dynamics. The patchy nature of the increase in NDVI will require the use of higher spatial resolution data from LANDSAT, SPOT and MODIS in order to determine the driving factors of change at the landscape scale. Further studies examining combined climate data including rainfall and sea surface temperature patterns and continued gathering of long-term satellite data sets will help in understanding the long-term changes in the climate and land surface conditions of this sensitive semi-arid environment.